NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

DASA-11.026

Technical Report R 350

GAMMA-RAY SHIELDING EFFECTS OF METAL DOORS IN DUCTS

11 January 1965

U. S. NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

GAMMA-RAY SHIELDING EFFECTS OF METAL DOORS IN DUCTS

Y-F008-08-05-201, DASA-11.026

Type C

by

P. R. Bryson and J. S. Grant

ABSTRACT

Results are presented of an experiment carried out on the shielding effects of a steel door in a two-legged 11 x 11-inch concrete duct using Co^{60} as a gamma-ray source. Two door positions and two door thicknesses were used. A relatively strong inscatter effect was measured when the door was placed at the corner where direct radiation was received. When a 3/8-inch steel door was placed in the second leg 22 inches from the corner, the radiation was reduced 50 to 60 percent. It can be expected that the farther down the second leg the door is placed, the less radiation it will transmit; that the thicker the door, the greater its shielding effectiveness will be. A method of scaling the results to large ducts is presented based on the experimental measurements.

INTRODUCTION

Experimental measurements of the effects of a steel door on the gamma-ray streaming in an 11-inch-square concrete duct were made as part of the radiation shielding studies being conducted at the U. S. Naval Civil Engineering Laboratory. The present work was done to secure information that might aid in determining the attenuation factor obtained by placing a steel door in the entranceway of a radiation shelter and to determine the effects of changing the thickness and location of the door. To make it possible to scale the results for the small experimental duct to large-sized entranceways, additional measurements were made to determine the contributions due to corner-lip penetration.

THEORETICAL CONSIDERATIONS

Considerable success has been achieved in explaining and calculating gamma-ray streaming in two-legged ducts using basic scattering principles.[1, 2, 3, 4] In harmony with these basic principles, duct streaming may be divided into two parts: that which is scattered from the surfaces within the duct without penetration, and that which penetrates the corner lip in the scattering process. The part of the streaming which involves only surface scattering is called the "scaling part" in this study because it is readily scaled from one duct size to another. When the leg lengths of the two ducts are in proportion to their widths, the scaling can be done by using the formula

$$Af_{(\text{large duct})} = Af_{(\text{small duct})} \left(\frac{\ell_1}{L_1}\right)^2$$

where Af is the attenuation factor, and ℓ_1 and L_1 are the first leg lengths or source distances, for the small and large ducts respectively. The source distances used in this investigation were 39.4 and 20.8 inches, measured from the intersection of the centerlines of the first and second legs.

The corner-lip effect does not scale with the size of the duct. The scaling part of the radiation was obtained by subtracting the corner-lip contribution from the total streaming in the following manner. The total dose rate in the second leg was measured with the duct open; then lead shielding was placed at the corner of the duct, and the corner-lip contribution was measured; the latter measurements were subtracted from the former to give the scaling contribution.

DESCRIPTION OF APPARATUS

A 2.2-currie Co^{60} source was used for most of the measurements and was considered to be a point source. It was necessary to use a 0.26-currie Co^{60} source when taking Geiger counts with the 20.8-inch first leg lengths because of the high count rate. These readings were normalized to the large source readings by using a factor of 8.5.

Dose rates were measured with 100-mr and 10-mr Landsverk dosimeters. These dosimeters have been compared and found to give slightly different readings, in the ratio of 1.05 to 1.00 respectively. A second 10-mr Landsverk dosimeter, used for a few of the early measurements, was found to give consistently lower readings than the other, with the ratio of 0.95 to 1.00. All dosimeter readings were converted to agree with the most used 10-mr dosimeter by using the appropriate conversion factors. Measurements that were to be critically compared were made with the same dosimeter when possible to minimize error from this source.

The Geiger counts were made as a general check of the results of the dosimeter measurements. The counts were made with a halogen-quenched tube with a stainless-steel case (Navy Type 5980/BS-2). The ratio of counts per second to milliroentgens per hour is believed to give some indication of the degradation of energy of the photons, with a relatively higher ratio indicating a higher proportion of low-energy components.

The concrete duct was formed in two sections. The first section, used as the first leg of a two-legged duct, consisted of a 40 x 40 x 24-inch block of concrete with the 11 x 11-inch duct running through it. The second leg was built up from blocks of convenient sizes to permit opening the duct for placement of the steel doors and lead shielding as required for the several tests. Figures 1 and 2 show two views of the duct. The lead shielding was accomplished by laying a 1 x 11 x 11-inch lead plate flat in the duct and stacking 2 x 4 x 8-inch lead bricks on it to completely block the opening.

THE EXPERIMENT

Steel Door Inscatter Measurements

Since it was expected that a steel door set at the corner where it would receive direct radiation from the source would furnish inscatter to the detector, measurements were made to determine this effect. Figure 3 illustrates the experimental arrangement. Lead bricks were used to eliminate corner-lip transmission, and the first leg was removed so as to eliminate secondary radiation. Thus only primary radiation was received by the door. Two source distances were used where the first leg would ordinarily be as indicated by dashed lines in Figure 3.

Dosimeter readings were made with the steel door at position A in the direct radiation; then similar measurements were made with the door at position B in the shadow of the lead bricks. The difference between those readings is the inscatter. Table I gives the data and computed inscatter for two different doors, 3/8-inch and 3/4-inch thick, with two source distances. Figure 4 shows the inscatter effect, with dose rate plotted against the distance from the center of the corner. Figure 5 is a graph of the Geiger-count inscatter data plotted against distance from the door in position A. This graph shows a nearly exact inverse-square relationship. It can be seen that for a source distance of 20.8 inches the inscatter of the thick door is greater than that of the thin door, whereas for a source distance of 39.4 inches just the opposite is true. This is probably due to the change in angle of incidence. The dosimeter data similarly plotted (Figure 6) shows a departure from an inverse-square relationship, indicating that the energy of the average photon is less for large values of L_2.

Two-Legged Duct Measurements

Door at the Corner. Measurements to determine the effect of the steel door when placed at the corner of the duct were made as illustrated in Figure 7 with (a) the steel door in place, (b) the duct open, and (c) the duct blocked with lead to measure the corner-lip effect. These measurements were made at several points in the second leg, using a 3/8-inch and a 3/4-inch door, with the source positioned for first leg lengths of 39.4 inches and 20.8 inches. The difference between the readings for the open duct and the lead-blocked duct is the scaling part of the radiation streaming. The difference between the readings with the steel door in place and the lead-blocked duct gives the transmission plus inscatter for the steel door. These results are shown in Figure 9 and Tables II and III. In each case the distance is measured from the point where the centerlines of the two legs cross. The importance of the door inscatter becomes apparent when it is noted that a large portion (from 40 to 90 percent) of the scaling radiation dose with the door at this corner is due to this inscatter effect.

Door 22 Inches in the Second Leg. Three sets of measurements were made with the thin door placed in the second leg 22 inches (twice the width of the duct) from the intersection of the centerlines of the legs: (a) with only the door in place, (b) with the passage blocked with lead next to the door, and (c) with the passage blocked with lead at the corner. (See Figure 8). The measurements were made with $L_1 = 39.4$ inches and with $L_1 = 20.8$ inches. The difference between the readings for just the steel door and the readings with the lead at the corner gives the transmission plus inscatter of the door. The data is given in Tables IV and V and plotted in Figure 9 together with the plots for the corner door effect. The measurements of part (b) were not considered important to the present problem, but the data was included since it shows there is some gamma-ray penetration of walls, ceiling, and floor even at this large distance down the second leg.

DISCUSSION

The Attenuation Factor of the Steel Door

The attenuation factor of a steel door can be defined as the ratio of the total dose rate with the door in place to the total dose rate without the door. When so defined, the door offers less shielding when the attenuation factor is higher.

The following results, obtained from Tables II, III, IV, and V, are found for the experimental duct. The attenuation factors expressed in percent are averages for the several dosimeter positions.

Door at Corner				Door 22 Inches From Corner	
$L_1 = 39.4$ in.		$L_1 = 20.8$ in.		$L_1 = 39.4$ in.	$L_1 = 20.8$ in.
Thick door	Thin door	Thick door	Thin door	Thin door	Thin door
79%	97%	87%	97%	45%	51%

Note that the door is most effective when placed in the second leg out of the corner region.

The graphs of Figures 10 through 13 summarize the attenuation factors for the doors as determined in the experiment.

Calculating the Attenuation Factor of a Steel Door in a Two-Legged Duct

The above results as they stand are of use only for a concrete duct with the dimensions of the experimental duct. If they are to be useful for other ducts, the effects in terms of scaling part and corner-lip contributions must be calculated separately. The results of the calculations are given in Tables VI and VII.

From the geometry it is apparent that the door, when placed at the corner, will have very little effect on the corner penetration part of the radiation.

To apply the percent attenuation factor values to a large duct, it is necessary first to know the fraction of the radiation which penetrates the corner, and second to assume that the percent attenuation of the corner part by the door remains the same for larger ducts. This latter appears to be likely from a consideration of the geometry, but measurements in larger ducts have not been made to confirm it.

For the relative amounts of corner effect and scaling part, use can be made of the computer code set up by Chapman[2] for calculating duct streaming in terms of primary and secondary scattering and corner effects. Table VIII gives some values for comparison.

To illustrate the method of scaling the experimental data to fit a large duct, the following example is given. The large duct in the example is 6 x 6 feet with $L_1 = 2W$ and $L_2 = 2.5W$. This scales with the 11 x 11-inch experimental duct with $L_1 = 20.8$ inches and $L_2 = 27$ inches.

Contribution	Attenuation Factor	
	Thin Door at Corner	Thin Door at 22 Inches
Scaling part	0.76 x 0.85 = 0.65 (65%)	0.76 x 0.38 = 0.29 (29%)
Corner part	0.24 x 1.00 = 0.24 (24%)	0.24 x 0.52 = 0.12 (12%)
Total effectiveness	89%	41%

In the first of the above calculations the factor 0.76 is the fraction of the streaming due to the scaling part and is taken from Chapman's calculations. The factor 0.85 is the fraction of transmission by the door at the corner taken from Table VI, which is data from the present experiment. The factor 1.00 in the corner part calculations is used because the door at the corner does not interfere with the corner penetration.

Effect of Location and Thickness of the Door

The door should be located down the second leg of the duct away from the corner where it will not receive direct radiation because of the strong inscatter effect. Also it is expected that the farther down the second leg from the corner the more degraded, on the average, will become the radiation. This is borne out by the comparison between Geiger-count and dose-rate data. Since the mass absorption coefficients are larger for lower energy photons, it can be expected that the farther down the leg the door is placed, the less radiation it will transmit. Some support of this is given by the fact that the door at 22 inches down the second leg of the duct passes only half as much radiation as when placed at the corner position.

The thicker the door, the greater will be its shielding effectiveness. One would expect that doubling the thickness would square the transmission fraction since the thickness appears in the exponent; i.e., $e^{-\mu x}$, where μ is the linear attenuation coefficient. This does not occur with the door at the corner, but this is due to the strong inscatter effect of the door. The relationship is expected to apply down the duct away from the corner where the door inscatter effect is missing.

Error in Dosimeter Readings

The manufacturer suggests that an error of 2 percent can be expected in the dosimeter readings. A study of the data indicates this to be a little too low, with 3 percent a better value. Allowing for 3 percent error in the readings, the resulting error in the attenuation factors of the door can be rather large. Using the relationships

$$\sigma(a - b) = \sqrt{[\sigma(a)]^2 + [\sigma(b)]^2}$$

and

$$\sigma\left(\frac{a}{b}\right) = \sqrt{\left(\frac{\sigma(a)}{b}\right)^2 + \left(\frac{a\,\sigma(b)}{b^2}\right)^2}$$

probable errors for these examples were worked out. The values are included in Tables VI and VII, and error bars are included in Figures 10, 11, and 13.

Making due allowance for dosimeter reading errors, it is apparent that the attenuation factor of the door when placed at the corner increases appreciably as L_2 (dosimeter positions) becomes longer. This means that the door at the corner removes a smaller fraction of the radiation at points successively farther from the corner.

When the door is two duct widths down the second leg, the attenuation factor increases a very small amount, if at all, with an increase in L_2.

On the above evidence, it is speculated that the effect of an increase of attenuation factor with an increase in L_2 becomes progressively less pronounced as the door is moved farther down the second leg.

FINDINGS

The attenuation factor of a steel door is high when placed at the corner of a two-legged duct. When placed at a point down the second leg a distance two times the duct width from the center of the corner, the 3/8-inch door removed 50 to 60 percent of the radiation. Greater reduction in transmitted dose is expected for thicker doors and for doors farther from the corner in the second leg.

ACKNOWLEDGMENTS

Appreciation is expressed to J. M. Chapman for his aid in performing the experiments and his fruitful discussion of the results.

REFERENCES

1. U. S. Naval Civil Engineering Laboratory. Technical Report R-289: Gamma-ray streaming through ducts, by C. M. Huddleston and W. L. Wilcoxson. Port Hueneme, Calif., Feb. 1964.

2. ______. Technical Report R-264: Computer calculations of dose rates in two-legged ducts using the albedo concept, by J. M. Chapman. Port Hueneme, Calif., Oct. 1963.

3. ______. Technical Report R-195: Attenuation of gamma radiation in a two-legged 11-inch rectangular duct, by D. W. Green. Port Hueneme, Calif., May 1962.

4. ______. Technical Report R-349: An empirical formula for calculating gamma-ray dose attenuation in concrete ducts, by W. C. Ingold and C. M. Huddleston. Nov. 1964.

Table I. Dosimeter and Geiger-Count Data for Steel Door Inscatter Measurements

L_2 Dosimeter Positions (in.)	Thick Door			Thin Door		
	Door Positions		Inscatter	Door Positions		Inscatter
	A	B		A	B	
L_1 = 39.4 inches (mr/hr)						
18	27.5	14.2	13.3	33.3	16.6	16.7
27	8.02	4.15	3.87	9.58	4.27	5.31
36	3.40	1.31	2.09	3.95	1.73	2.22
(counts/min)						
18	4,600	2,600	2,000	5,400	3,048	2,352
27	1,463	802	634	1,660	871	789
36	623	300	323	710	326	384
L_1 = 20.8 inches (mr/hr)						
18	150.3	42.1	108.2	159.7	49.5	110.2
27	52.3	16.0	36.3	53.1	17.7	35.4
36	21.92	5.05	16.87	21.8	6.0	15.8
(counts/min)						
18	21,500	7,360	14,140	21,600	8,600	13,000
27	7,700	2,970	4,730	7,590	3,280	4,310
36	3,270	990	2,280	3,180	1,120	2,060

Table II. Dosimeter and Geiger-Count Data for Steel Door Experiments With L_1 = 39.4 Inches and Door at Corner

L_2 Dosimeter Positions (in.)	Open Duct (a)	Thick Door (b)	Thin Door (c)	Lead and Thin Door (d)	Total Scaling Part of Transmission (a-d)	Transmission and Inscatter of Door	
						Thick (b-d)	Thin (c-d)
(mr/hr)							
13.5	230	190	215	156	74	34	59
18.0	99.4	82.8	93.2	61.5	37.9	21.3	31.7
22.5	51.6	39.8	47.7	28.1	23.5	11.7	19.6
27.0	29.1	21.8	27.2	14.9	14.2	6.9	12.3
31.5	18.0	14.2	17.2	8.7	9.3	5.5	8.5
36.0	12.6	9.6	11.8	5.8	6.8	3.8	6.0
(counts/min)							
18.0	16,500	12,240	14,100	8,540	7,960	3,700	5,560
27.0	5,490	396	4,580	2,410	3,080	1,550	2,170
36.0	2,510	1,780	2,090	957	1,550	822	1,130
(ratio of counts/min to mr/hr)							
18.0	2.76	2.46	2.52	2.31	3.50	3.89	2.92
27.0	3.14	3.02	2.81	2.70	3.60	3.73	2.95
36.0	3.32	3.08	2.96	2.75	3.79	3.61	3.12

Table III. Dosimeter and Geiger-Count Data for Steel Door Experiments With L_1 = 20.8 Inches and Door at Corner[1/]

L_2 Dosimeter Positions (in.)	Open Duct (a)	Thick Door (b)	Thin Door (c)	Lead and Thin Door (d)	Total Scaling Part of Transmission (a-d)	Transmission and Inscatter of Door: Thick (b-d)	Transmission and Inscatter of Door: Thin (c-d)
(mr/hr)							
13.5	2,270	1,930	2,150	1,780	490	157	371
18.0	1,014	888	978	789	225	98.8	181
22.5	507	437	486	385	122	52.3	102
27.0	268	233	257	194	74	39	62.7
31.5	151	127	148	104	47.5	23.8	44.7
36.0	89.0	79.0	90.5	60.6	28.4	18.4	29.9
(counts/min)							
18.0	146,000	133,000	137,000	114,000	32,000	19,000	23,000
27.0	43,000	35,800	39,000	28,200	14,800	7,600	10,800
36.0	16,300	12,900	14,300	9,200	7,100	3,700	5,100
(ratio of counts/min to mr/hr)							
18.0	2.39	2.49	2.33	2.40	2.36	3.20	2.11
27.0	2.67	2.55	2.52	2.43	3.31	3.23	2.84
36.0	3.05	2.70	2.62	2.51	4.16	3.34	2.84

1/ The dosimeter readings were made with the 100-mr dosimeter, and the Geiger-count readings were made with the small source. Both sets of readings were converted to agree with the other data.

Table IV. Dosimeter and Geiger-Count Data for Steel Door Experiment With L_1 = 39.4 Inches and Thin Door at L_2 = 2W (22 inches)

L_2 Dosimeter Positions (in.)	Door at 22 Inches (a)	Door at 22 Inches, Lead at Corner (b)	Door and Lead at 22 Inches (c)	Transmission Plus Inscatter of Door (a-b)
		(mr/hr)		
27.0	12.7	7.0	1.20	5.70
31.5	8.37	4.21	0.97	4.16
36.0	5.67	2.88	0.82	2.79
		(counts/min)		
27.0	2,234	1,070	184	1,164
31.5	1,445	682	157	763
36.0	1,009	468	137	541
		(ratio of counts/min to mr/hr)		
27.0	2.94	2.56	2.62	3.39
31.5	2.87	2.70	2.68	3.05
36.0	2.95	2.70	2.77	3.23

Table V. Dosimeter and Geiger-Count Data for Steel Door Experiment With L_1 = 20.8 Inches and Thin Door at L_2 = 2W (22 inches)[1/]

L_2 Dosimeter Positions (in.)	Door at 22 Inches (a)	Door at 22 Inches, Lead at Corner (b)	Door and Lead at 22 Inches (c)	Transmission Plus Inscatter of Door (a-b)
(mr/hr)				
27.0	139	106	16.0	33.0
31.5	80.3	62.2	16.8	18.1
36.0	48.2	34.3	9.3	13.9
(counts/min)				
27.0	19,600	14,700	2,220	4,900
31.5	12,200	8,760	2,440	3,440
36.0	7,360	5,100	1,320	2,260
(ratio of counts/min to mr/hr)				
27.0	2.35	2.31	2.31	2.47
31.5	2.52	2.34	2.41	3.15
36.0	2.53	2.47	2.39	2.70

1/ The dosimeter readings were made with the 100-mr dosimeter, and the Geiger-count readings were made with the small source. Both sets of readings were converted to agree with the other data.

Table VI. Attenuation Factors by the Door at the Corner (Scaling part)

L_2 Dosimeter Positions (in.)	L_1 = 39.4 Inches		L_1 = 20.8 Inches	
	Thick Door (%)	Thin Door (%)	Thick Door (%)	Thin Door (%)
13.5	46 ± 10.6	80	32	76
18.0	56 ± 9.6	83	41	81
22.5	50 ± 7.2	83	43	83
27.0	49 ± 6.5	87	53	85
31.5	59 ± 6.6	91	50	95
36.0	56 ± 6.1	88	65	106

Table VII. Attenuation Factors by the Thin Door at L_2 = 2W

L_2 Dosimeter Positions (in.)	L_1 = 39.4 Inches		L_1 = 20.8 Inches	
	Corner Part (%)	Scaling Part (%)	Corner Part (%)	Scaling Part (%)
27.0	47	40 ± 4	55	45 ± 9
31.5	48	45 ± 4	60	38 ± 8
36.0	50	41 ± 1.5	57	49 ± 8

Table VII. The Fractions of Duct Streaming Due to Corner Effect and to Scaling Part

Method	Square Duct	L_1	L_2	Corner Lip	Scaling Part
Experiment	11 x 11-inch	39.4"	27"	51%	49%
Experiment	11 x 11-inch	20.8"	27"	72%	28%
Chapman Calculations[2]	11 x 11-inch	20.8"	27"	67%	33%
Chapman Calculations[2]	6 x 6-foot	2W	2.5W	24%	76%
Ingold Calculations[4]	6 x 6-foot	4W	4W	15%	85%
Ingold Calculations[4]	6 x 6-foot	4W	6W	11%	89%

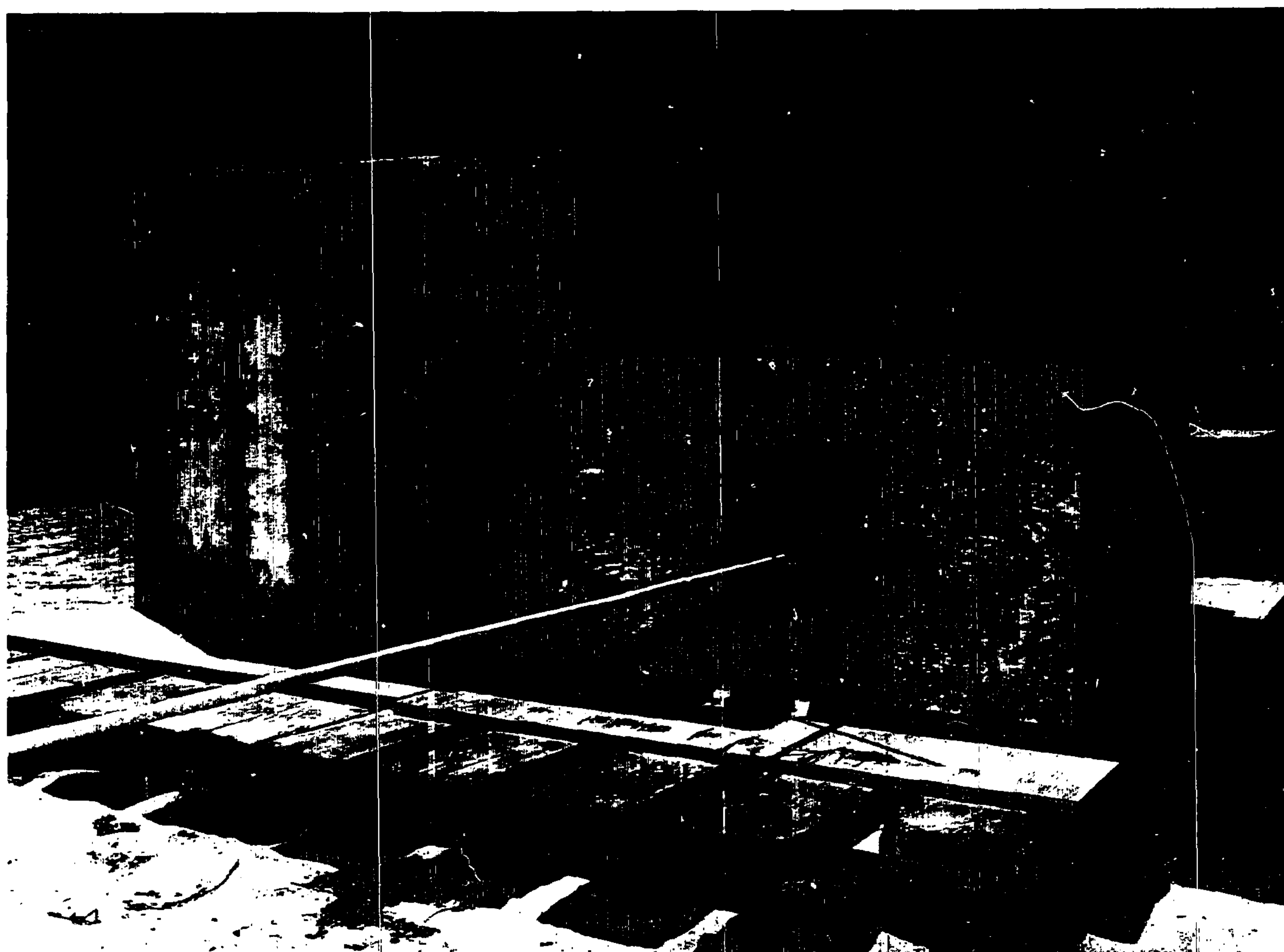

Figure 1. Photograph of first leg of duct.

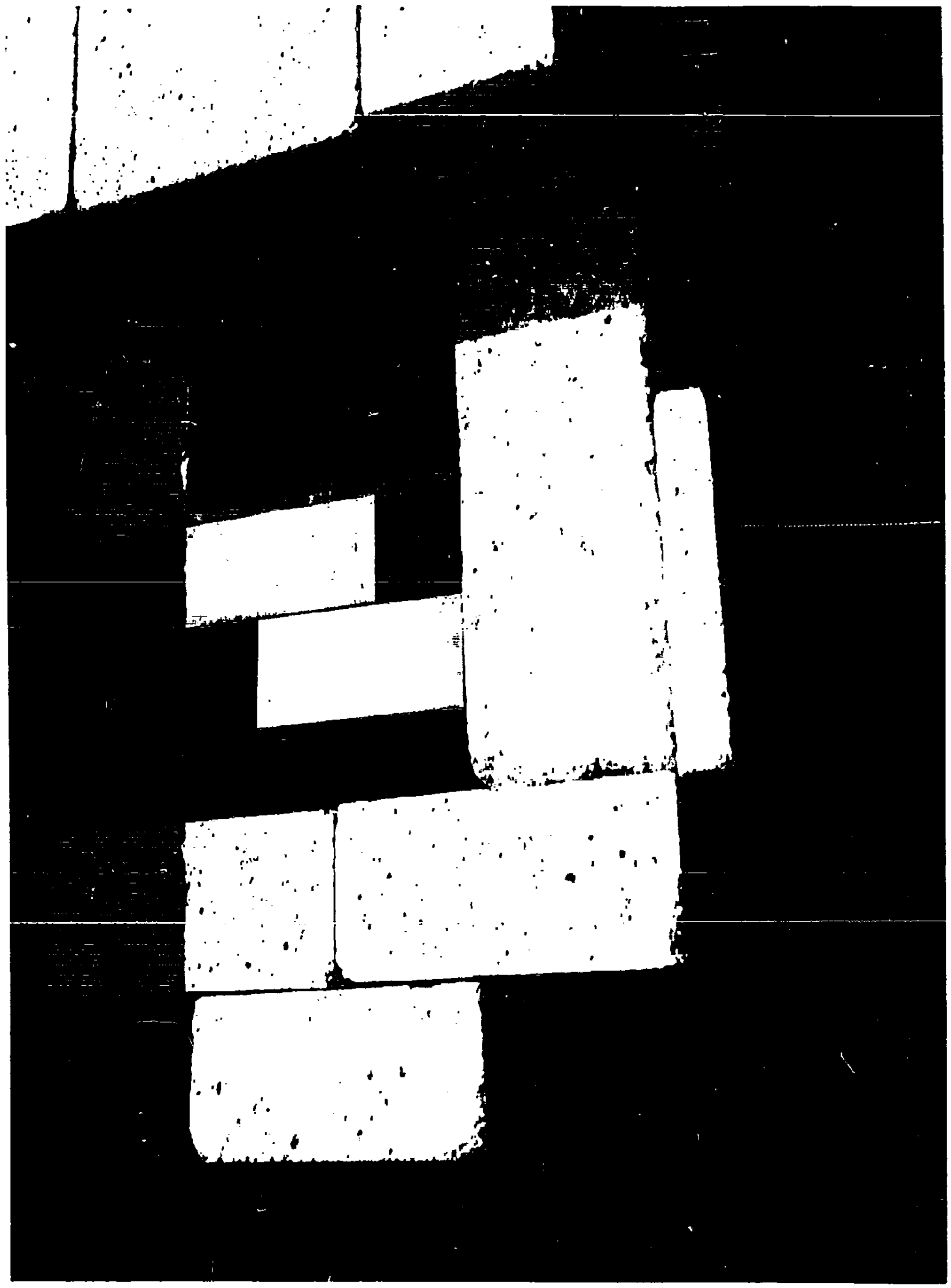

Figure 2. Photograph of second leg of duct showing steel door and lead in place.

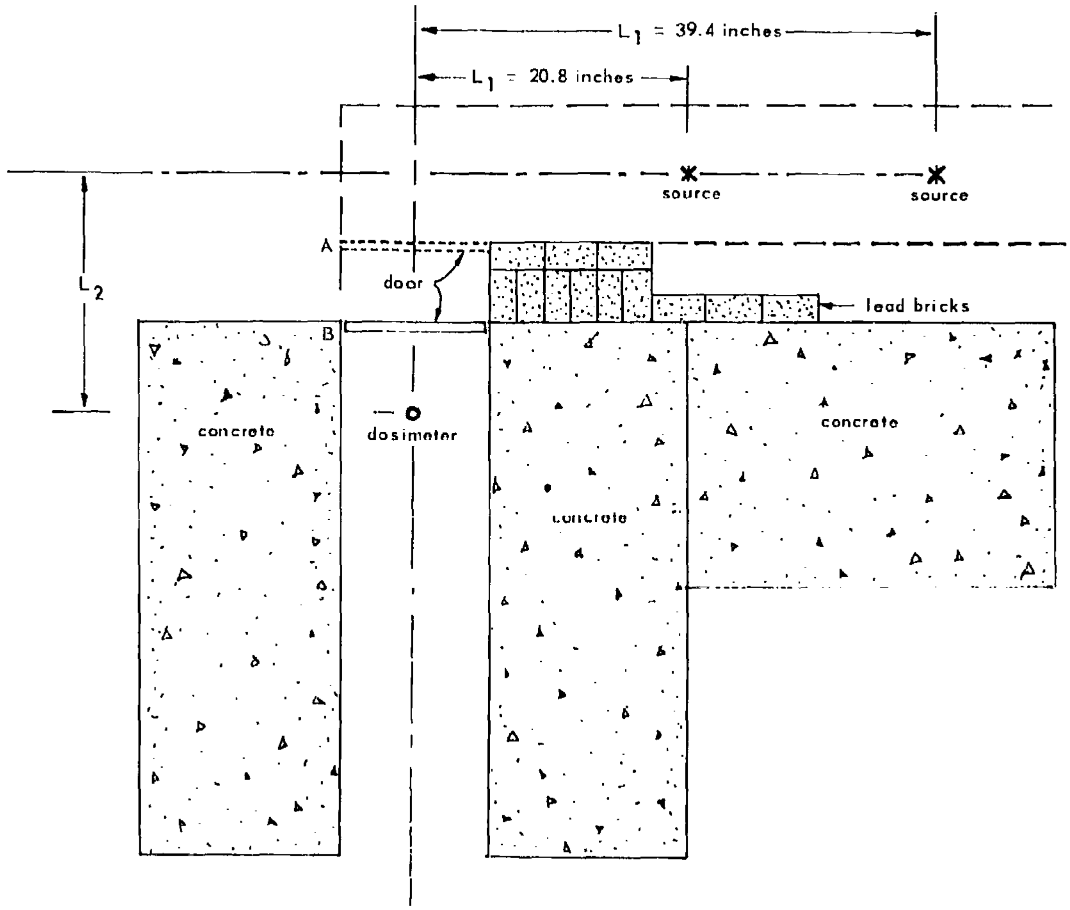

Figure 3. Plan view of inscatter experiment, with the first leg removed (indicated by dashed lines) to eliminate secondary radiation. The measurements were made with the door at position A and then position B.

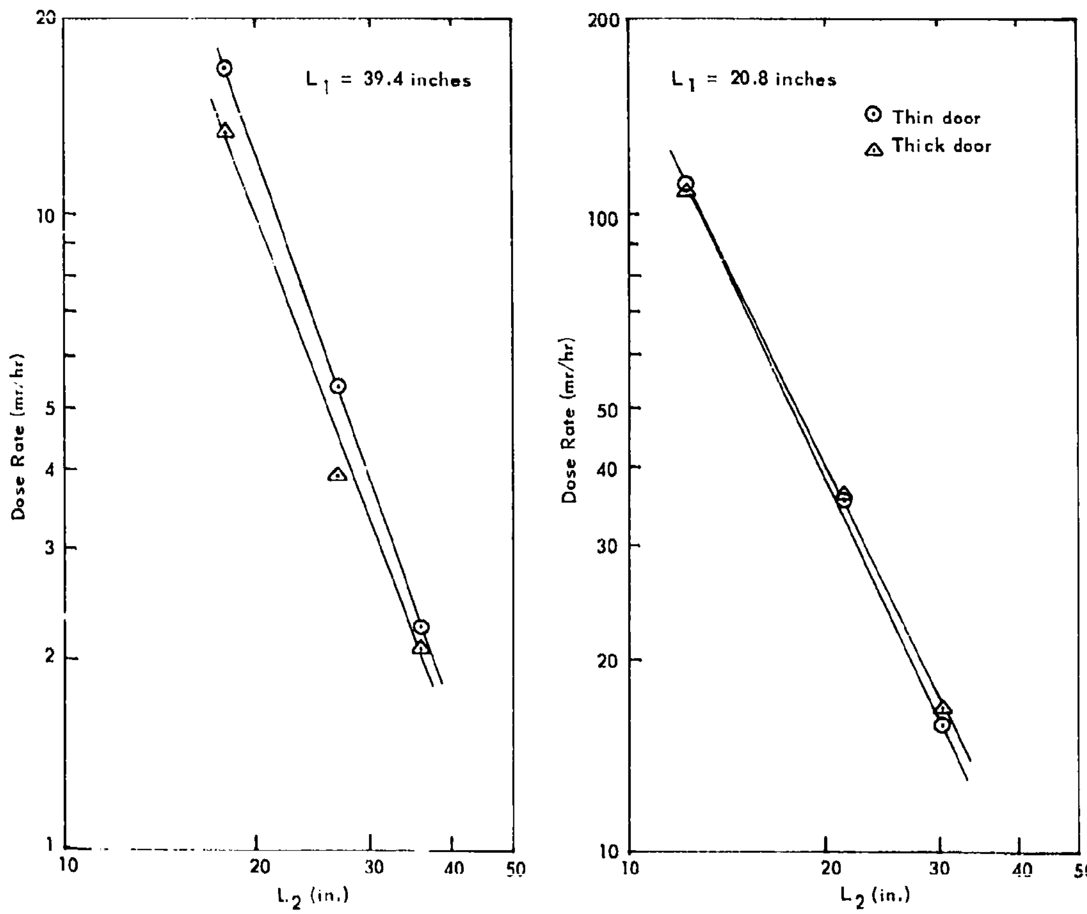

Figure 4. Dose rate due to inscatter from the steel door. The distance is measured from the center of the corner.

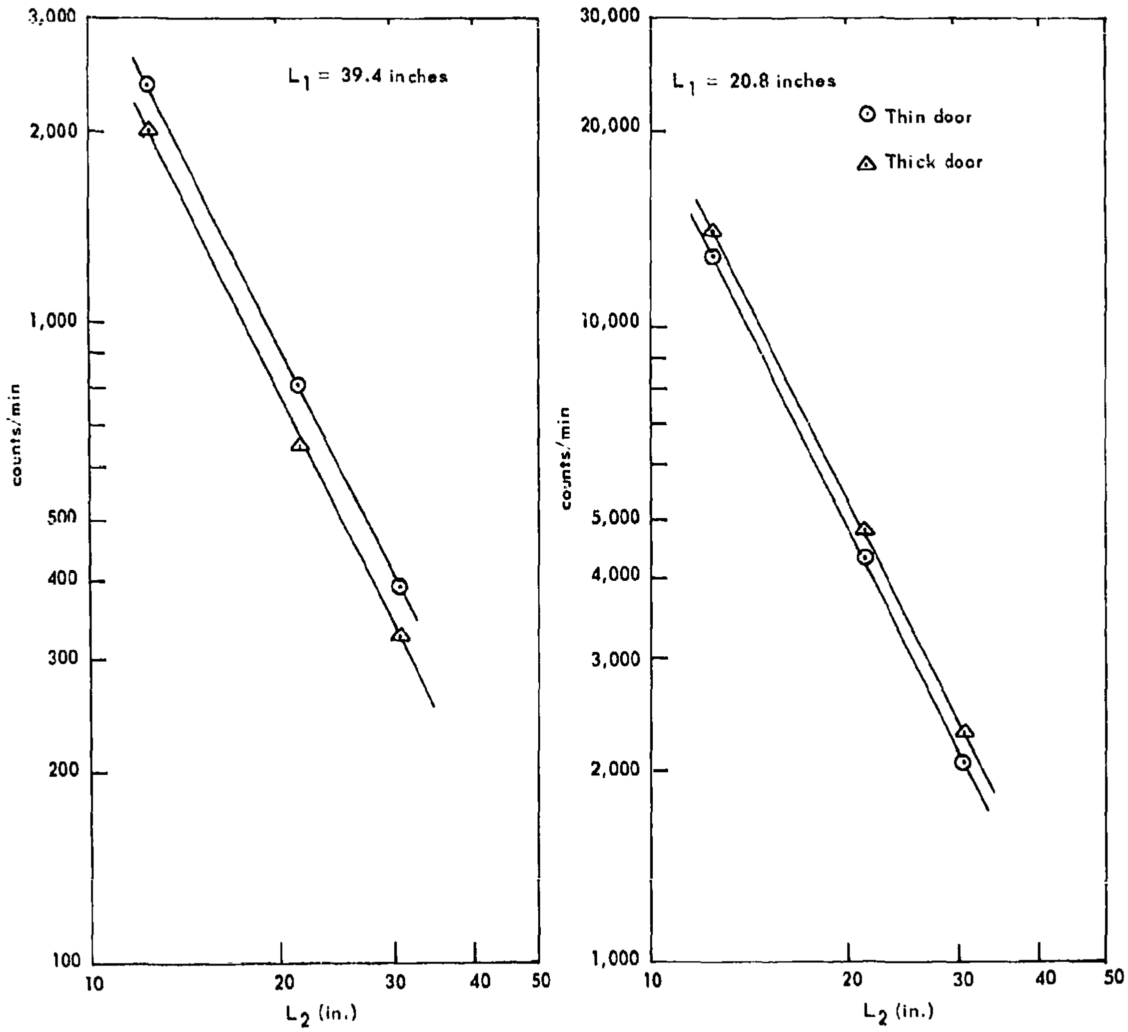

Figure 5. Geiger-count inscatter data. The distance is measured from the steel door in position A.

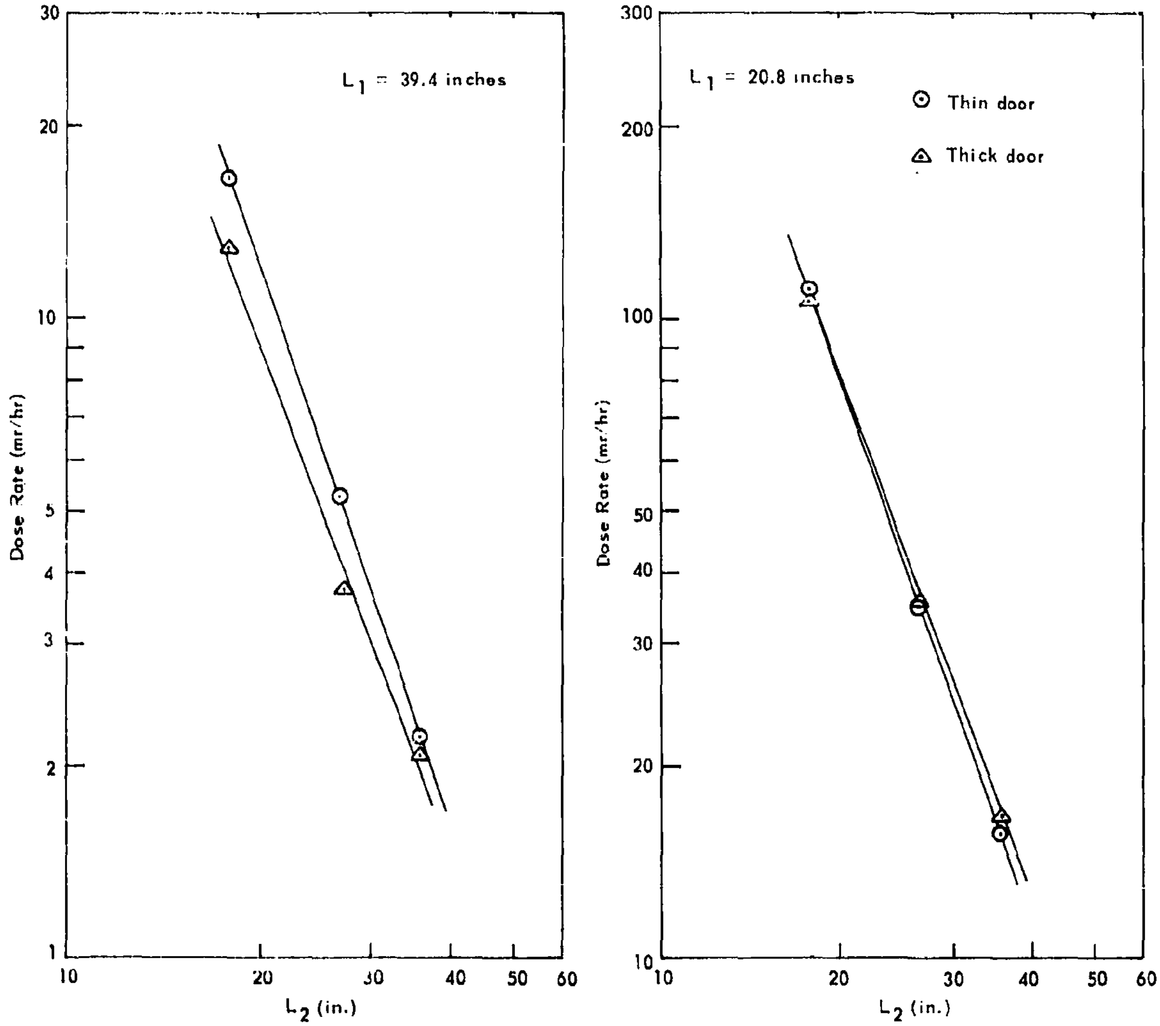

Figure 6. Dosimeter readings. The distance is measured from the steel door in position A.

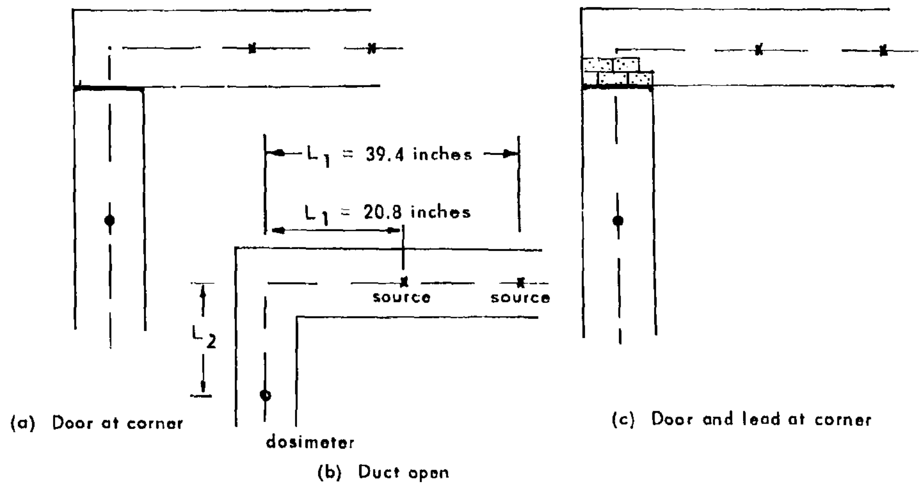

Figure 7. Diagrams of two-legged duct as used in determining the effect of the steel door in the corner, showing the method of blocking the duct with lead for measuring the corner-lip effect.

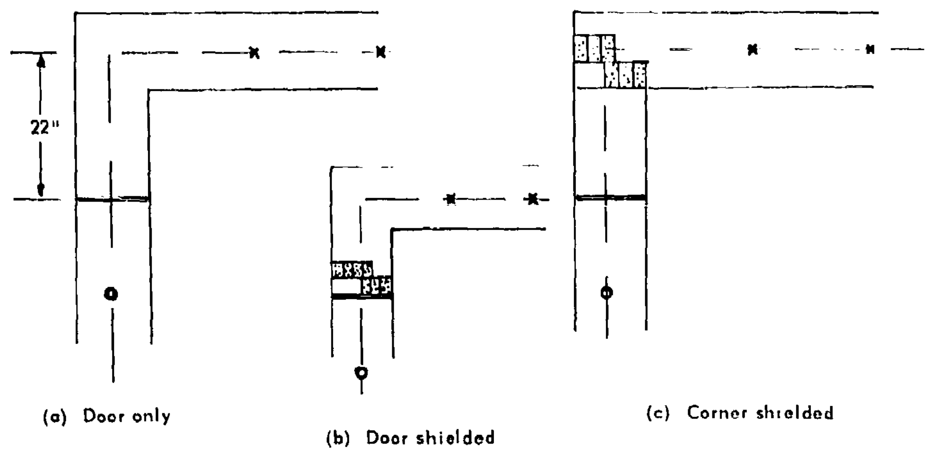

Figure 8. Diagrams of two-legged duct as used in determining the effect of the steel door 22 inches in the second leg.

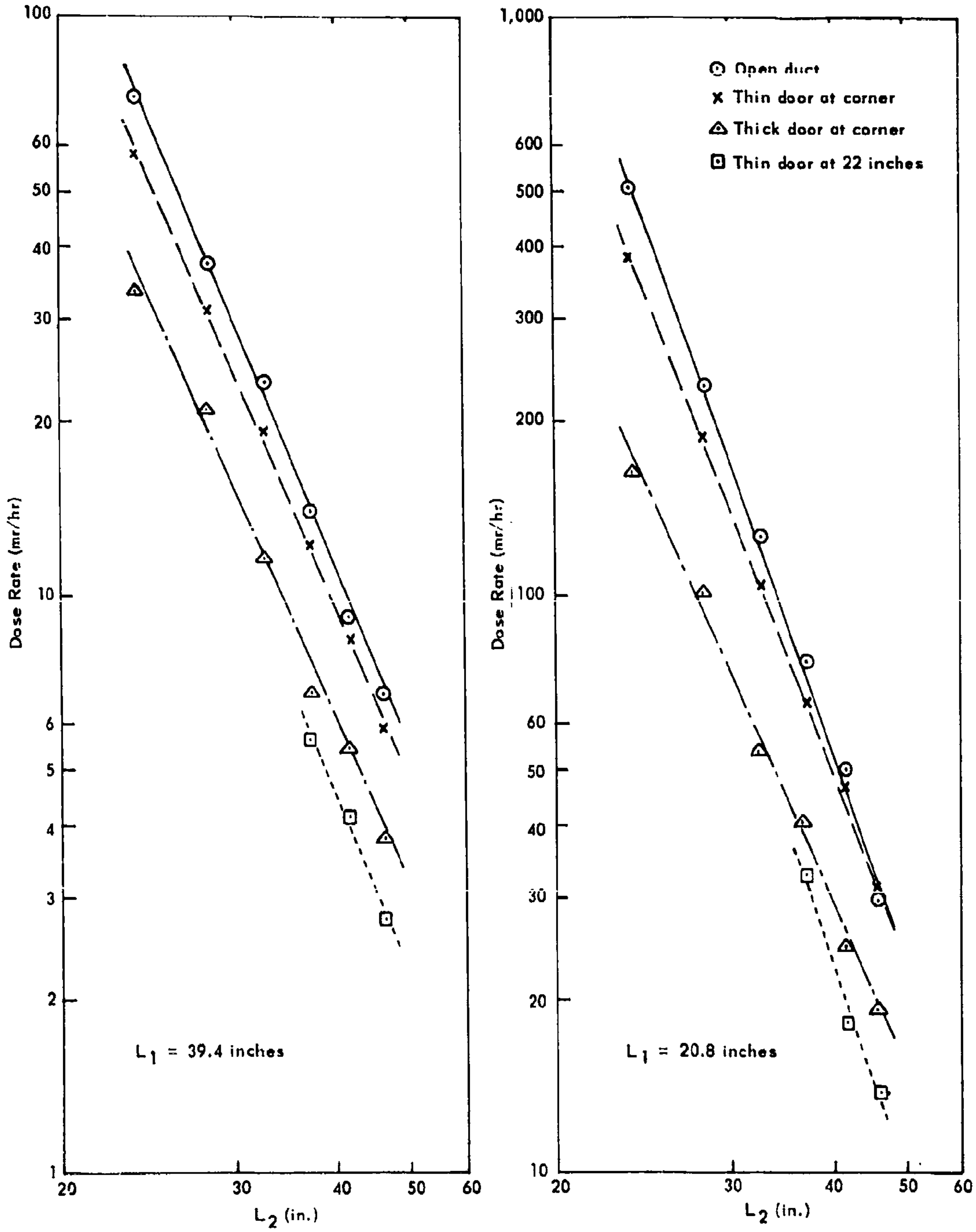

Figure 9. Dose rate due to transmission plus inscatter for the steel door at two positions in the duct.

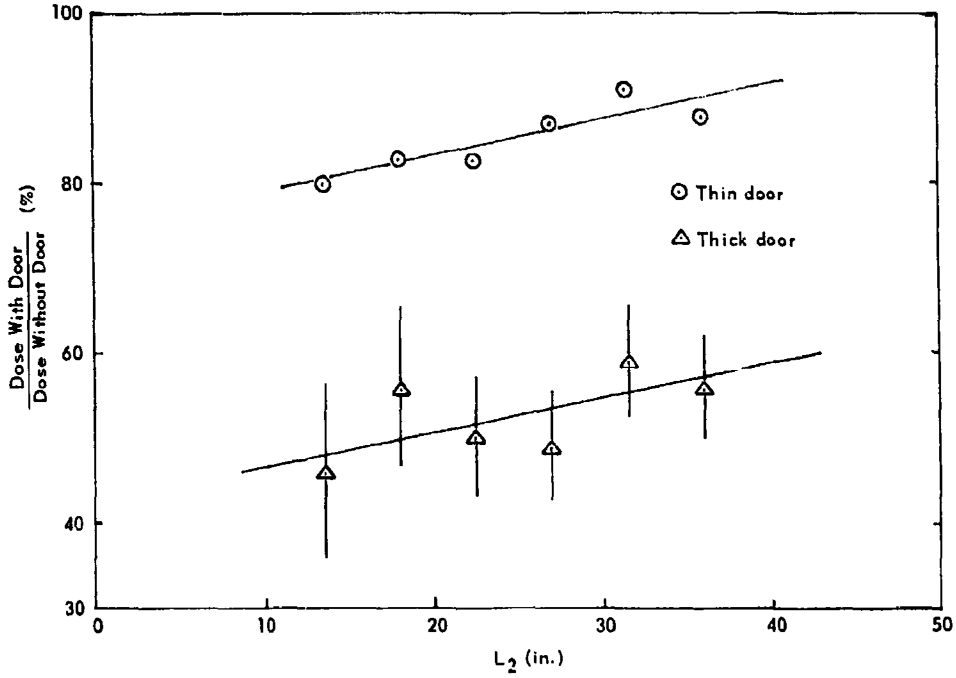

Figure 10. The effect of the attenuation factor of the door on the scaling part of the radiation when the door is at the corner and L_1 = 39.4 inches.

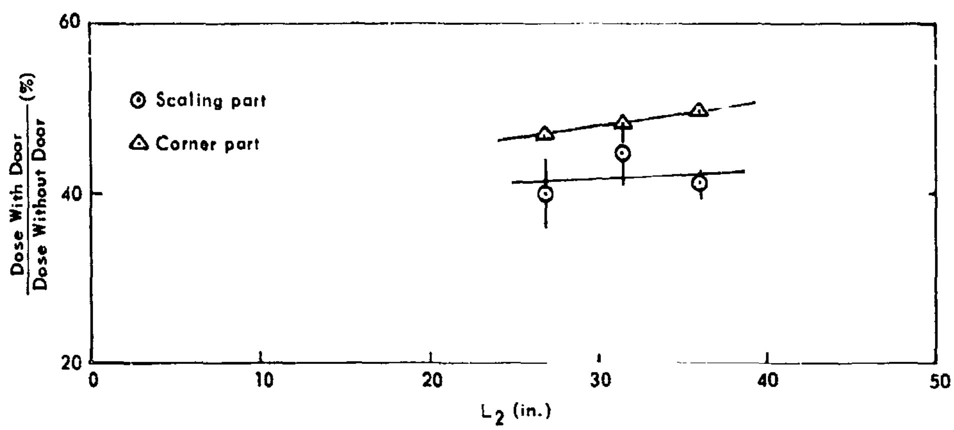

Figure 11. The attenuation factor of the thin door when the door is 22 inches from the corner and L_1 = 39.4 inches.

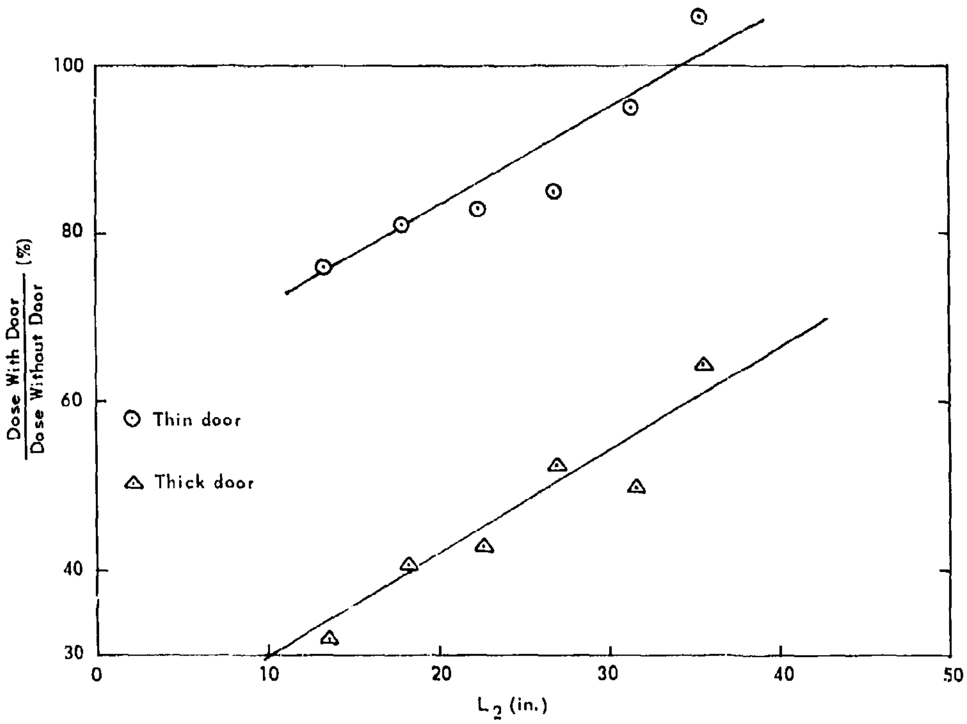

Figure 12. The effect of attenuation factor of the door on the scaling part of the radiation when the door is at the corner and L_1 = 20.8 inches.

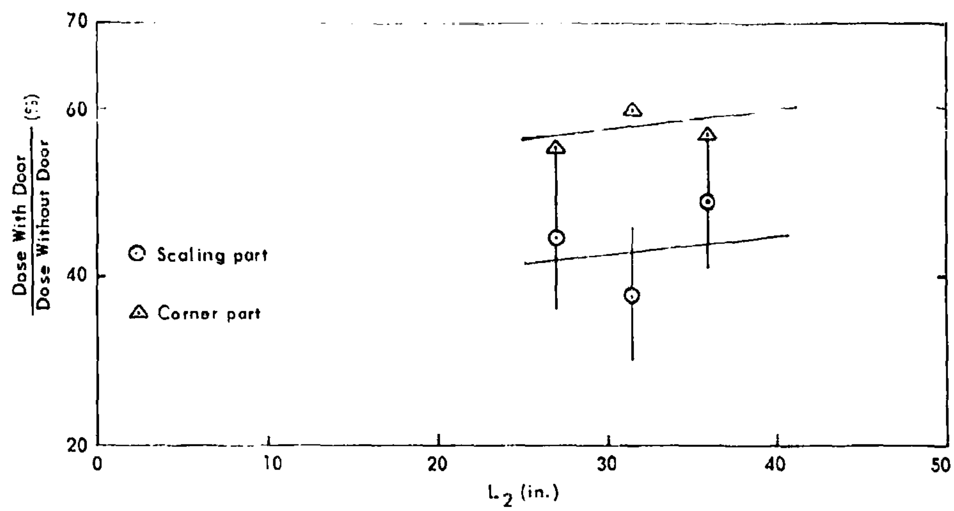

Figure 13. The attenuation factor of the door when the door is 22 inches from the corner and L_1 = 20.8 inches.

DISTRIBUTION LIST

SNDL Code	No. of Activities	Total Copies	
	1	25	Chief, Defense Atomic Support Agency, Washington, D. C.
	1	10	Chief, Bureau of Yards and Docks (Code 42)
23A	1	1	Naval Forces Commanders (Taiwan only)
39B	2	2	Construction Battalions
39D	5	5	Mobile Construction Battalions
39E	3	3	Amphibious Construction Battalions
39F	1	2	Construction Battalion Base Units
A2A	1	1	Chief of Naval Research - Only
A3	2	2	Chief of Naval Operation (OP-07, OP-04)
A5	5	5	Bureaus
B3	2	2	Colleges
E4	1	2	Laboratory ONR (Washington, D. C. only)
E5	1	1	Research Office ONR (Pasadena only)
E16	1	1	Training Device Center
F9	7	7	Station – CNO (Boston; Key West; San Juan; Long Beach; San Diego; Treasure Island; and Rodman, C. Z. only)
F17	6	6	Communication Station (San Juan; San Francisco; Pearl Harbor; Adak, Alaska; and Guam only)
F41	1	1	Security Station
F42	1	1	Radio Station (Oso and Cheltanham only)
F48	1	1	Security Group Activities (Winter Harbor only)
F61	2	2	Naval Support Activities (London and Naples only)
F77	1	1	Submarine Base (Groton, Conn. only)
F81	2	2	Amphibious Bases
H3	7	7	Hospital (Chelsea; St. Albans, Portsmouth, Va.; Beaufort; Great Lakes; San Diego; and Camp Pendleton only)
H6	1	1	Medical Center
J1	2	2	Administration Command and Unit – BuPers (Great Lakes and San Diego only)
J3	1	1	U. S. Fleet Anti-Air Warfare Training Center (Virginia Beach only)
J19	1	1	Receiving Station (Brooklyn only)
J34	1	1	Station – BuPers (Washington, D. C. only)

DISTRIBUTION LIST (Cont'd)

SNDL Code	No. of Activities	Total Copies	
J46	1	1	Personnel Center
J48	1	1	Construction Training Unit
J60	1	1	School Academy
J65	1	1	School CEC Officers
J84	1	1	School Postgraduate
J90	1	1	School Supply Corps
J95	1	1	School War College
J99	1	1	Communication Training Center
L1	11	11	Shipyards
L7	4	4	Laboratory – BuShips (New London; Panama City; Carderock; and Annapolis only)
L26	5	5	Naval Facilities – BuShips (Antigua; Turks Island; Barbados; San Salvador; and Eleuthera only)
L42	2	2	Fleet Activities – BuShips
M27	4	4	Supply Center
M28	6	6	Supply Depot (except Guantanamo Bay; Subic Bay; and Yokosuka)
M61	2	2	Aviation Supply Office
N1	6	18	BuDocks Director, Overseas Division
N2	9	27	Public Works Offices
N5	3	9	Construction Battalion Center
N6	5	5	Construction Officer-in-Charge
N7	1	1	Construction Resident-Officer-in-Charge
N9	6	12	Public Works Center
N14	1	1	Housing Activity
R9	2	2	Recruit Depots
R10	2	2	Supply Installations (Albany and Barstow only)
R20	1	1	Marine Corps Schools (Quantico)
R64	3	3	Marine Corps Base
R66	1	1	Marine Corps Camp Detachment (Tengan only)
W1A1	6	6	Air Station
W1A2	35	35	Air Station
W1B	8	8	Air Station Auxiliary

DISTRIBUTION LIST (Cont'd)

SNDL Code	No. of Activities	Total Copies	
W1C	3	3	Air Facility (Phoenix; Naha; and Naples only)
W1E	6	6	Marine Corps Air Station (except Quantico)
W1H	9	9	Station – BuWeps (except Rota)
	1	1	Deputy Chief of Staff, Research and Development, Headquarters, U. S. Marine Corps, Washington, D. C.
	1	1	President, Marine Corps Equipment Board, Marine Corps School, Quantico, Va.
	1	1	Chief of Staff, U. S. Army, Chief of Research and Development, Department of the Army, Washington, D. C.
	1	1	Office of the Chief of Engineers, Assistant Chief of Engineering for Civil Works, Department of the Army, Washington, D. C.
	1	1	Chief of Engineers, Department of the Army, Washington, D. C., Attn: Engineering Research and Development Division
	1	1	Chief of Engineers, Department of the Army, Washington, D. C., Attn: ENGCW-OE
	1	3	Headquarters, U. S. Air Force, Directorate of Civil Engineering, Washington, D. C., Attn: AFOCE-ES
	1	1	Commanding Officer, U. S. Naval Construction Battalion Center, Port Hueneme, Calif., Attn: Materiel Dept., Code 140
	1	1	Deputy Chief of Staff, Development, Director of Research and Development, Department of the Air Force, Washington, D. C.
	1	1	Director, National Bureau of Standards, Department of Commerce, Connecticut Avenue, Washington, D. C.
	1	2	Office of the Director, U. S. Coast and Geodetic Survey, Washington, D. C.
	1	20	Defense Documentation Center, Building 5, Cameron Station, Alexandria, Va.
	1	2	Director of Defense Research and Engineering, Department of Defense, Washington, D. C.
	1	2	Director, Bureau of Reclamation, Washington, D. C.
	1	1	Facilities Officer, Code 108, Office of Naval Research, Washington, D. C.
	1	1	Federal Aviation Agency, Office of Management Services, Administrative Services Division, Washington, D. C., Attn: Library Branch

DISTRIBUTION LIST (Cont'd)

No. of Activities	Total Copies	
1	2	Commander Naval Beach Group Two, U. S. Naval Amphibious Base, Little Creek, Norfolk, Va.
1	1	Commander, Pacific Missile Range, Technical Documentation Section, P. O. Box 10, Point Mugu, Calif., Attn: Code 4332
1	2	U. S. Army Engineer Research and Development Laboratories, Attn: STINFO Branch, Fort Belvoir, Va.
1	1	Director, U. S. Naval Ordnance Laboratory, White Oak, Silver Springs, Md.
1	1	Office of Naval Research, Branch Office, Navy No. 100, Box 39, FPO, New York
1	1	U. S. Naval Radiological Defense Laboratory, San Francisco
1	1	Officer in Charge, CECOS, Port Hueneme, Calif., Attn: ADCE Course
1	1	U. S. Air Force, Asst. Chief of Staff, Intelligence, Building B, AHS, Washington, D. C., Attn: Mr. Sargent White
1	1	Commander, Space Systems Division, Los Angeles Air Force Station, Los Angeles, Calif. Attn. SSSO
1	1	Directorate of Research, Air Force Weapons Laboratory, Kirtland Air Force Base, N. M.
1	1	Office of the Chief of Engineers, Department of the Army, T-7, Gravelly Point, Washington, D. C., Attn: ENGNB
1	1	Commanding Officer, Engineer Research and Development Laboratories, Fort Belvoir, Va.
1	1	Office of the Chief of Engineers, Department of the Army, T-7, Gravelly Point, Washington, D. C., Attn: ENG MC-EB
1	1	Director, U. S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss., Attn: Mr. G. L. Arbuthnot, Jr.
1	1	U. S. Army Chemical Center, Nuclear Defense Laboratory, Edgewood, Md.
1	1	Director, Ballistic Research Laboratories, Aberdeen, Md.
1	2	Chief, Defense Atomic Support Agency, Washington, D. C.
1	1	Headquarters, Field Command, Defense Atomic Support Agency, Sandia Base, Albuquerque, N. M.
1	1	U. S. Atomic Energy Commission, Technical Information Service, P. O. Box 62, Oak Ridge, Tenn.
1	1	Director, Civil Effects Test Group, Atomic Energy Commission, Washington, D. C.
1	1	Formulation and Analysis Branch, Mathematics and Computation Laboratory, National Resource Evaluation Center, Office of Emergency Planning, Washington, D. C.
1	2	Library of Congress, Washington, D. C.

DISTRIBUTION LIST (Cont'd)

No. of Activities	Total Copies	
1	1	Disaster Recovery Training Officer, Code 450, Construction Battalion Center, Davisville, R. I.
1	1	Mr. William J. Taylor, Terminal Ballistics Laboratory, Aberdeen Proving Ground, Md.
1	1	LCDR Charles W. Gulick, Jr., CEC, USN, Navy No. 926, FPO, San Francisco
1	1	CDR J. C. LeDoux, Bureau of Yards and Docks, Department of the Navy, Washington, D. C.
1	1	CAPT W. M. McLellon, CEC, USN, Ret., 468 1st Street, Albany, N. Y.
1	1	LT Edward S. Perry, U. S. Naval Reserve Officers Training Corps Unit, University of Illinois, Urbana, Ill.
1	1	CAPT L. N. Saunders, CEC, USN, Code C10, U. S. Naval Construction Battalion Center, Port Hueneme, Calif.
1	1	CDR E. M. Saunders, CEC, USN, Chief of Naval Materiel, Department of the Navy, Washington, D. C.
1	1	CDR J. D. Andrews, CEC, USN, Executive Officer, U. S. Naval Civil Engineering Laboratory, Port Hueneme, Calif.
1	1	CDR R. C. Vance, CEC, USN, Logistics Director, U. S. Naval Civil Engineering Laboratory, Port Hueneme, Calif.
1	1	CDR W. A. Walls, CEC, USN, Disaster Control Division, Bureau of Yards and Docks, Washington, D. C.
1	1	LT COL Charles D. Daniel, USA, Defense Atomic Support Agency, Washington, D. C.
1	1	Mr. L. Neal FitzSimons, Office of Civil Defense, Department of Defense, Washington, D. C.
1	1	Mr. Ben Taylor, Office of Civil Defense, Department of Defense, Washington, D. C.
1	1	Mr. Charles M. Eisenhauer, Radiation Physics Laboratory, National Bureau of Standards, Washington, D. C.
1	1	Mr. O. H. Hill, Building 12, Room 505, Radiation Physics Division, National Bureau of Standards, Washington, D. C.
1	1	LCDR T. Yoshihara, CEC, USN, ROICC, Southeast Asia, APO 143, San Francisco
1	1	CAPT W. J. Christensen, CEC, USN, Commanding Officer and Director, U. S. Naval Civil Engineering Laboratory, Port Hueneme, Calif.
1	1	CDR J. F. Dobson, CEC, USN, Officer of Civil Defense, Department of the Army, Washington, D. C.
1	1	LCDR O. L. Dixon, CEC, USN, U. S. Naval School, CEC Officers, Port Hueneme, Calif.
1	1	LCDR N. W. Clements, CEC, USN, Navy Nuclear Power Unit, Fort Belvoir, Va.
1	1	CDR C. Curione, CEC, USN, Resident Officer-In-Charge-Of-Construction, Long Beach Area, P. O. Box XX, Seal Beach, Calif.

DISTRIBUTION LIST (Cont'd)

No. of Activities	Total Copies	
1	1	LT L. K. Donovan, CEC, USN, U. S. Naval Communication Station, Navy No. 85, FPO, San Francisco
1	1	LCDR Walter J. Eager, Jr., CEC, USN, AFRI-NNMC, Bethesda, Md.
1	1	CDR W. J. Francy, CEC, USN, United States Naval Academy, Annapolis, Md.
1	1	Dr. Lauriston S. Taylor, Chief, Radiation Physics Division, National Bureau of Standards, Washington, D. C.
1	1	Dr. James O. Buchanan, Research Directorate, Office of Civil Defense, Washington, D. C.
1	1	Mr. Jack C. Greene, Office of Civil Defense, Department of Defense, Washington, D. C.
1	1	Dr. Harold A. Knapp, Fallout Studies Branch, Division of Biology and Medicine, U. S. Atomic Energy Commission, Washington, D. C.
1	1	Dr. Karl Z. Morgan, Director, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.
1	1	Dr. Joseph D. Coker, National Resource Evaluation Center, Executive Office Building, Washington, D. C.
1	1	Dr. Charles F. Ksanda, Military Evaluation Division, U. S. Naval Radiological Defense Laboratory, San Francisco
1	1	Mr. John Auxier, Oak Ridge National Laboratory, Oak Ridge, Tenn.
1	1	Dr. William Kreger, Naval Radiological Defense Laboratory, San Francisco
1	1	Dr. Hans Tiller, Nuclear Defense Laboratory, Army Chemical Center, Md.
1	1	Mr. Irving Gaskill, National Resource Evaluation Center, Executive Office Building, Washington, D. C.
1	1	Mr. George Sisson, Office of Civil Defense, Department of Defense, Washington, D. C.
1	1	Mr. James C. Pettee, National Resource Evaluation Center, Executive Office Building, Washington, D. C.
1	1	LCDR I. D. Crowley, CEC, USN, Blast and Shock Division, Defense Atomic Support Agency, Washington, D. C.
1	1	CAPT H. L. Murphy, Room 211, Federal Office Building, San Francisco
1	1	LCDR W. H. Bannister, CEC, USN, Field Command, Defense Atomic Support Agency, Sandia Base, Albuquerque, N. M.

DISTRIBUTION LIST (Cont'd)

No. of Activities	Total Copies	
1	1	Major Robert Crawford, USAF, Air Force Weapons Laboratory, Kirtland Air Force Base, Alburquerque, N. M.
1	1	Dr. John Balloch, Director, Operations Analysis, 26th Air Division, SAGE, Hancock Field, Syracuse, N. Y.
1	1	Mr. J. F. Tamanini, A & E Development Division, Office of Civil Defense, Department of Defense, Washington, D. C.
1	1	CDR C. R. Whipple, CEC, USN, Armed Forces Staff College, Norfolk, Va.
1	1	Dr. W. E. Fisher, Air Force Weapons Laboratory, Kirtland Air Force Base, Albuquerque, N. M.
1	1	Mr. Everitt P. Blizard, Director, Neutron Physics, Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn.
1	1	LT M. MacDonald, CEC, USN, U. S. Naval School, CEC Officers, Port Hueneme, Calif.
1	1	Library, Engineering Department, University of California, 405 Hilgard Avenue, Los Angeles
1	1	Sandia Corporation, Box 5800, Albuquerque, N. M.
1	1	Rivers and Harbor Library, Princeton University, Princeton, N. J.
1	1	Head, Civil Engineering Department, Carnegie Institute of Technology, Schenley Park, Pittsburgh, Pa.
1	1	Mr. G. H. Albright, Head, Department of Architectural Engineering, 101 Engineering "A" Bldg., The Pennsylvania State University, University Park, Pa
1	1	Dr. Lewis V. Spencer, Ottawa University, Physics Department, Ottawa, Kan.
1	1	Dr. N. M. Newmark, Civil Engineering Hall, University of Illinois, Urbana, Ill.
1	1	Professor J. Neils Thompson, Civil Engineering Department, University of Texas, Austin, Tex.
1	1	Mr. Fred Sauer, Physics Department, Stanford Research Institute, Menlo Park, Calif.
1	1	Dr. T. H. Schiffman, Armour Research Foundation of Illinois, Institute of Technology, Technology Center, Chicago, Ill.
1	1	Dr. Robert V. Whitman, Massachusetts Institute of Technology, Cambridge, Mass.
1	1	Mr. E. E. Shalowitz, Protective Construction, GSA Building, 19th and F Streets, N. W., Washington, D. C.
1	1	CDR Allen F. Dill, CEC, USNR, Public Works Officer, Headquarters Support Activity, Taipei, Box 25, APO 63, San Francisco

DISTRIBUTION LIST (Cont'd)

No. of Activities	Total Copies	
1	1	Mr. Werner Weber, Nuclear Engineering Consultant, N. Y. State Civil Defense Commission, P. O. Box 7007, State Office Building, Albany, N. Y.
1	1	Dr. Harold Brode, The Rand Corporation, 1700 Main Street, Santa Monica, Calif.
1	1	Mr. R. D. Cavanaugh, Barry Controls, Inc., 700 Pleasant Street, Watertown, Mass.
1	1	Mr. Kenneth Kaplan, Broadview Research Corporation, 1811 Trousdale Drive, Burlingame, Calif.
1	1	Mr. Thomas Morrison, American Machine and Foundry Company, 7501 North Natchez Avenue, Niles, Ill.
1	1	Mr. Walter Gunther, The Mitre Corporation, P. O. Box 208, Lexington, Mass.
1	1	Mr. W. R. Perret – 5112, Applied Experiments Division, Sandia Corporation, Albuquerque, N. M.
1	1	Mr. Lyndon Welch, Eberle M. Smith Associates, Inc., 153 East Elizabeth Street, Detroit, Mich.
1	1	Professor Herbert M. Bosch, Public Health Engineering, School of Public Health, University of Minnesota, Minneapolis, Minn.
1	1	Dr. Merit P. White, Civil Engineering Department, School of Engineering, University of Massachusetts, Amherst, Mass.
1	1	Dr. Robert J. Hansen, Department of Civil & Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.
1	1	Mr. Harold Horowitz, Building Research Institute, National Academy of Sciences, 2101 Constitution Avenue, N. W., Washington, D. C.
1	1	Mr. Luke Vortman – 5112, Applied Experiments Division, Sandia Corporation, Albuquerque, N. M.
1	1	Mr. Richard Park, National Academy of Sciences, 2101 Constitution Avenue, N. W., Washington, D. C.
1	1	Mr. Frederick A. Pawley, AIA Research Secretary, American Institute of Architects, 1735 New York Avenue, N. W., Washington, D. C.
1	1	Dr. E. E. Massey, Defense Research Board, Department of National Defense, Ottawa, Canada
1	1	Dr. Robert Rapp, The Rand Corporation, 1700 Main Street, Santa Monica, Calif.
1	1	Dr. Stephen B. Withey, Program Director, Survey Research Center, University of Michigan, Ann Arbor, Mich.
1	1	Dr. Eric T. Clarke, Technical Operations, Inc., Burlington, Mass.
1	1	Dr. A. B. Chilton, Civil Engineering Hall, University of Illinois, Urbana, Ill.
1	1	Mrs. Shea Valley, CRTZS, A. F. Cambridge Research Center, L. G. Hanscom Field, Bedford, Mass.
1	1	Dr. J. T. Hanley, Department of Civil Engineering, University of Minnesota, Minneapolis, Minn.

DISTRIBUTION LIST (Cont'd)

No. of Activities	Total Copies	
1	1	Chief, Bureau of Ships, Attn: Chief of Research and Development Division, Navy Department, Washington, D. C.
1	1	Officer in Charge, U. S. Naval Biological Laboratory, Naval Supply Center, Oakland, Calif.
1	1	Officer in Charge, U. S. Navy Unit, Rensselaer Polytechnic Institute, Troy, N. Y.
1	1	Chief, Bureau of Medicine and Surgery, Attn: Research Division, Navy Department, Washington, D. C.
1	1	Officer in Charge, U. S. Naval Supply Research and Development Facility, Naval Supply Center, Attn: Library, Bayonne, N. J.
1	1	Director, Marine Physical Laboratory, U. S. Navy Electronics Laboratory, San Diego, Calif.
1	1	Chief, Bureau of Naval Weapons, Attn: Research Division, Navy Department, Washington, D. C.
1	1	Commander, Pacific Missile Range, Attn: Technical Director, Point Mugu, Calif.
1	1	Officer in Charge, U. S. Naval Supply Research and Development Facility, Naval Supply Center, Bayonne, N. J.
1	1	Commander, Norfolk Naval Shipyard, Attn: Chemical Laboratory, Portsmouth, Va.
1	1	Commanding Officer, Fleet Training Center, Navy No. 128, FPO, San Francisco, Calif.
1	1	Commander, U. S. Naval Shipyard, Attn: Rubber Laboratory, Mare Island, Vallejo, Calif.
1	1	Commander, U. S. Naval Shipyard, Attn: Material Laboratory, Brooklyn 1, N. Y.
1	1	Office of Naval Research, Branch Office, Navy No. 100, Box 39, FPO, N. Y.
1	1	Commanding Officer, Naval Electronics Laboratory, Attn: Technical Director, San Diego, Calif.
1	1	Commanding Officer, U. S. Naval Unit, U. S. Army Chemical Corps School, Fort McClellan, Ala.
1	1	U. S. Naval Research Laboratory, Chemistry Division, Washington, D. C.
1	1	Commanding Officer, Field Research Laboratory, Bureau of Medicine and Surgery, Camp Lejeune, N. C.
1	1	Deputy Chief of Staff, Research & Development Headquarters, U. S. Marine Corps, Washington, D. C.
1	1	Commanding Officer, Signal Corps Engineering Labs, Fort Monmouth, N. J.
1	1	Directorate of Medical Research, Chemical Warfare Laboratory, Army Chemical Center, Md.
1	1	U. S. Army Cold Regions Research and Engineering Laboratory, Corps of Engineers, P. O. Box 282, Hanover, N. H.

DISTRIBUTION LIST (Cont'd)

No. of Activities	Total Copies	
1	1	Coles Signal Laboratory, Red Bank, N. J.
1	1	Air Force Cambridge Research Center, Hanscom Field, Mass.
1	1	Directorate of Research, Air Force Special Weapons Center, Kirtland Air Force Base, N. M.
1	1	Arctic Aeromedical Laboratory, United States Air Force, APO 731, Seattle, Wash.
1	1	Commanding Officer, Biological Warfare Laboratories, Fort Detrick, Frederick, Md.
1	1	Sandia Corporation, Attn: Classified Document Division, Box 5800, Albuquerque, N. M.
1	1	Chief, Physical Research Branch, Research Division, U. S. Department of Commerce, Bureau of Public Roads, Washington, D. C.
1	1	Department of Zoology, Duke University, Durham, N. Car.
1	1	Director, Engineering Research Institute, University of Michigan, Ann Arbor, Mich.
1	1	Director, Marine Laboratory, University of Miami, Coral Gables, Fla.
1	1	Director, Soil Physics Laboratory, Department of Engineering, Princeton University, Princeton University, Princeton, N. J.
1	1	Director, The Technological Institution, Northwestern University, Evanston, Ill.
1	1	John F. Batter, CONESCO, Inc., 205 Sixth Street, Cambridge, Mass.
1	1	Prof. D. W. Green, 1668 Maple Avenue, Galesburg, Ill.
1	1	John H. Hubbell, National Bureau of Standards, Washington, D. C.
1	1	Robert M. Kinkaid, Edgerton, Germeshausen, and Greer, Inc., P. O. Box 1912, Las Vegas, Nev.
1	1	Dr. R. L. Ashley, Atomics International, P. O. Box 309, Canoga Park, Calif.
1	1	Ballistic Research Laboratories, Director, Aberdeen, Md.
1	1	Civil Effects Test Group, Director, Atomic Energy Commission, Washington, D. C.
1	1	Library, University of Alaska, Fairbanks, Alaska
1	1	Library, Battelle Institute, Columbus, Ohio
1	1	Library, University of Southern California, University Park, Los Angeles, Calif.
1	1	Library, Institute of Technology, University of Minnesota, Minneapolis, Minn.
1	1	Library, California Institute of Technology, Pasadena, Calif.
1	1	Dr. H. E. Stanton, Physics Division, Argonne National Laboratory, Argonne, Ill.
1	1	Dr. C. W. Terrell, Armour Research Foundation, 10 West 35th Street, Chicago, Ill.
1	1	S. K. Penny, Radiation Shielding Information Center, Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn.

DISTRIBUTION LIST (Cont'd)

No. of Activities	Total Copies	
1	1	Professor J. Silverman, Department of Chemical Engineering, University of Maryland, College Park, Md.
1	1	Dr. F. T. Mavis, Dean, College of Engineering, University of Maryland, College Park, Md.
1	1	Dr. Raymond R. Fox, Associate Professor and Director, Protective Construction Courses, The George Washington University, Washington, D. C.
1	1	Professor M. L. P. Go, Civil Engineering Department, University of Hawaii, Honolulu, Hawaii
1	1	Dr. James P. Romualdi, Department of Civil Engineering, Carnegie Institute of Technology, Pittsburg, Pa.
1	1	Dr. Nicholas Perrone, Structural Mechanics Branch, Office of Naval Research, Department of the Navy, Washington , D. C.
1	1	Dr. Aleksandar Sedmak Vesić, Associate Professor, Georgia Institute of Technology, Atlanta, Georgia
1	1	Mr. C. C. Mow, The Rand Corporation, 1700 Main Street, Santa Monica, Calif.
1	1	Systems Engineering Group, Deputy for Systems Engineering, Directorate of Technical Publications and Specifications, Wright-Patterson AFB, Ohio
1	1	Dr. William L. White, Stanford Research Institute, Menlo Park, Calif.

U. S. Naval Civil Engineering Laboratory
GAMMA-RAY SHIELDING EFFECTS OF METAL DOORS IN DUCTS,
by P. R. Bryson and J. S. Grant
TR-350 35 p. illus 11 Jan 65 Unclassified

1. Radiation shielding — shelters Y-F008-03-05-201 DASA-11.026

Results are presented of an experiment carried out on the shielding effects of a steel door in a two-legged 11 x 11-inch concrete duct using Co^{60} as a gamma-ray source. Two door positions and two door thicknesses were used. A relatively strong inscatter effect was measured when the door was placed at the corner where direct radiation was received. When a 3/8-inch steel door was placed in the second leg 22 inches from the corner, the radiation was reduced 50 to 60 percent. It can be expected that the farther down the second leg the door is placed, the less radiation it will transmit; that the thicker the door, the greater its shielding effectiveness will be. A method of scaling the results to large ducts is presented based on the experimental measurements.

U. S. Naval Civil Engineering Laboratory
GAMMA-RAY SHIELDING EFFECTS OF METAL DOORS IN DUCTS,
by P. R. Bryson and J. S. Grant
TR-350 35 p. illus 11 Jan 65 Unclassified

1. Radiation shielding — shelters Y-F008-08-05-201 DASA-11.026

Results are presented of an experiment carried out on the shielding effects of a steel door in a two-legged 11 x 11-inch concrete duct using Co^{60} as a gamma-ray source. Two door positions and two door thicknesses were used. A relatively strong inscatter effect was measured when the door was placed at the corner where direct radiation was received. When a 3/8-inch steel door was placed in the second leg 22 inches from the corner, the radiation was reduced 50 to 60 percent. It can be expected that the farther down the second leg the door is placed, the less radiation it will transmit; that the thicker the door, the greater its shielding effectiveness will be. A method of scaling the results to large ducts is presented based on the experimental measurements.

U. S. Naval Civil Engineering Laboratory
GAMMA-RAY SHIELDING EFFECTS OF METAL DOORS IN DUCTS,
by P. R. Bryson and J. S. Grant
TR-350 35 p. illus 11 Jan 65 Unclassified

1. Radiation shielding — shelters Y-F008-08-05-201 DASA-11.026

Results are presented of an experiment carried out on the shielding effects of a steel door in a two-legged 11 x 11-inch concrete duct using Co^{60} as a gamma-ray source. Two door positions and two door thicknesses were used. A relatively strong inscatter effect was measured when the door was placed at the corner where direct radiation was received. When a 3/8-inch steel door was placed in the second leg 22 inches from the corner, the radiation was reduced 50 to 60 percent. It can be expected that the farther down the second leg the door is placed, the less radiation it will transmit; that the thicker the door, the greater its shielding effectiveness will be. A method of scaling the results to large ducts is presented based on the experimental measurements.

U. S. Naval Civil Engineering Laboratory
GAMMA-RAY SHIELDING EFFECTS OF METAL DOORS IN DUCTS,
by P. R. Bryson and J. S. Grant
TR-350 35 p. illus 11 Jan 65 Unclassified

1. Radiation shielding — shelters Y-F008-08-05-201 DASA-11.026

Results are presented of an experiment carried out on the shielding effects of a steel door in a two-legged 11 x 11-inch concrete duct using Co^{60} as a gamma-ray source. Two door positions and two door thicknesses were used. A relatively strong inscatter effect was measured when the door was placed at the corner where direct radiation was received. When a 3/8-inch steel door was placed in the second leg 22 inches from the corner, the radiation was reduced 50 to 60 percent. It can be expected that the farther down the second leg the door is placed, the less radiation it will transmit; that the thicker the door, the greater its shielding effectiveness will be. A method of scaling the results to large ducts is presented based on the experimental measurements.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Naval Civil Engineering Laboratory Port Hueneme, California 93041	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

Gamma-Ray Shielding Effects of Metal Doors in Duct

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final subtask 20 June 1964 - 30 August 1964

5. AUTHOR(S) (Last name, first name, initial)

Bryson, P. R.
Grant, J. S.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
11 January 1965	35	4

8a. CONTRACT OR GRANT NO. DASA-11.026	9a. ORIGINATOR'S REPORT NUMBER(S) TR-350
b. PROJECT NO. Y-F008-08-05-201	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. AVAILABILITY/LIMITATION NOTICES

Qualified requesters may obtain copies of this report from DDC.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	BUDOCKS - DASA

13. ABSTRACT

Results are presented of an experiment carried out on the shielding effects of a steel door in a two-legged 11 x 11-inch concrete duct using Co^{60} as a gamma-ray source. Two door positions and two door thicknesses were used. A relatively strong inscatter effect was measured when the door was placed at the corner where direct radiation was received. When a 3/8-inch steel door was placed in the second leg 22 inches from the corner, the radiation was reduced 50 to 60 percent. It can be expected that the farther down the second leg the door is placed, the less radiation it will transmit; that the thicker the door, the greater its effectiveness will be. A method of scaling the results to large ducts is presented based on the experimental measurements.

DD FORM 1 JAN 64 1473 0101-807-6800

Unclassified

Security Classification

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Radiation shielding	8					
Gamma rays	9					
Attenuation	8					
Steel	10					
Doors	10					
Ducts	9					
Shelters	9					
Subsurface structures	9					

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
______________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
______________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
______________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS), (S), (C), or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.

Unclassified
Security Classification